

Thank you for the opportunity to comment on the "Exploration Beyond LEO" document. I am 53 years old, an author of four technical books (in computer science), a successful entrepreneur, with masters degrees in nuclear engineering and operations research. I have followed the space program since childhood: I recall staying home from school to watch every Gemini and Apollo launch, writing to NASA to request literature on the space program, and being enthralled with articles on research on advanced propulsion concepts and what those might mean for future space travel.

Since the Apollo Program ended, I have been very disheartened. I feel that the Shuttle was a program designed to give the large contractors something to do, and the space station was definitely nothing but that. I also feel that space has become big business, and that it has become too expensive to do anything. It used to be that research was done at skunk works, often on a shoe string, but now any project contracted by NASA seems to be in the billion dollar range. Under that model, we will not be able to advance, because it makes every program a high risk program financially, and so there is so much scrutiny and attention to timelines, schedules, and safety that there is no flexibility for engineers to improvise. I also feel that all of the exciting research has ended. It appears that the research on advanced high energy (e.g., nuclear) propulsion, which is the only way that we will move forward, has dried up.

In light of this perspective, please consider the proposals that follow.

#### **Destinations and sequences of exploration for human exploration beyond LEO.**

I believe that exploration - not science - should be the fundamental and primary mission of NASA. Science should be funded by the NSF. NASA should be about exploration for its own sake.

Exploration should attempt to push the envelope, in both manned and un-manned modes. Toward that end, we should continue unmanned planetary missions of increasing ambition, and we should attempt to establish a presence on the Moon and on Mars and eventually beyond. Neither the Moon or Mars is better than the other: we need to plan for both, over time, as part of a long-term program of pushing outward.

Safety should not be our first concern. Exploration is dangerous, and NASA should publicly acknowledge this. NASA should stop sending teachers into space, for god's sake. It should be sending test pilots. Stop these PR stunts!

#### **Mode of surface exploration.**

Surface exploration should also attempt to push the envelope. Rather than re-invent the wheel (literally), we should be trying to create increasingly advanced exploration vehicles. Vehicular research for surfacer exploration should be part of the program. This might include approaches such as ground effect vehicles that can travel large distances quickly. Do you know the saying "fish or cut bait"? - let's fish!

#### **Coordinating human and robotic exploration.**

Robotic exploration is one method of extending human reach. It should therefore be part of both the manned and un-manned programs. I would expect advanced approaches to be tried, for example using

autonomous systems based on neural networks instead of traditional programming; but this is a matter to be determined by research, trial and error, and continuously trying to push the envelope. There need to be R&D programs that have the freedom to fail or to take longer than expected, but with pressure to achieve results rather than to complete a system within budget that does not push the envelope.

#### **Launch vehicle(s) to LEO (in terms of mass to orbit and shroud diameter).**

NASA should be trying out every mode of launch that is potentially feasible, and seeing which wins. This should include nuclear propulsion concepts if the radiation can be managed at a remote launch site to keep the public safe. The public needs to understand that nuclear rockets (e.g., micro pellet-based impulse fission or fusion systems) are not nuclear power plants, and that nuclear power is the only feasible way known to achieve high concentrations of energy that are needed for long-range manned flight in a reasonable time period. This includes launch vehicles, although it is more critical for inter-planetary operation. Launch vehicles using traditional booster technology should be as cheap and rudimentary as possible: they are not reusable and do not push the envelop, so invest little in them. Invest deeply only in things that push the envelop, such as single-stage-to-orbit concepts and nuclear concepts.

#### **Fuel/oxidizer storage and transfer.**

The space station should be leveraged for this; but with a nuclear approach, the need for this might be reduced....

I believe a case can be made for an Earth-Moon shuttle (a-la the cancelled NERVA project) if it turns out that fuel can be made more cheaply on the moon, and certainly if we plan to establish a presence on the moon. But instead of taking decades and billions to design every aspect of this, let's just do it the way that we did in the 60s: try it in steps until we get there.

#### **Space technology research and development.**

Guiding principle: push the envelope, in the interest of both manned and un-manned exploration. Toward this end, pursue any research to help realize these goals. Identify the impediments to enhancing human reach (e.g., distance, time, radiation) and conceptualize systems to overcome those impediments - and then build prototypes and try them. Do not create big projects that take on a life for their own sake: create aggressive (DARPA-style) prototype projects to test ideas, and then build systems around the prototypes that are successful. All the while, deploy operational systems that move us incrementally closer to our goals, so that we are not stuck in a research mode. Don't break the bank with the operational systems: make sure that there is lots of money for the research and piloting of risky but high return approaches.

#### **Engaging international partners.**

Absolutely. But keeping programs small is critical, to keep them from becoming political. Success should be measured based on the ultimate goals of extending human reach - not on the completion of a program to build some system. International political success should be kept separate from measures of NASA's success: NASA needs to be focused on its own goals, and not be distracted by worrying how the public will perceive the international activities or composition of any international effort. Do we see

such political posturing for other efforts such as the LHC? No, not the way that NASA has experienced with projects such as ISS. We need to get the international politics out of space exploration, to the extent that we can.

**Engaging commercial entities.**

Yes: they are free to use their own program management approaches that might be much more efficient and you can pick the ones that work. But let's not make a joke out of this: space tourism is fine, but it is not our true goal. NASA's true goal should be human exploration, and it should leverage commercial entities on a case-by-case basis if and only if doing so furthers NASA's goal.

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Best regards,

Clifford Berg